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TECHNICAL REPORT

TR75-118 AMEL

SIMULATED SOLAR HEAT TESTS OF M.U.S.T. AIR-INFLATABLE, DOUBLE-WALL HOSPITAL WARD SHELTERS

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MAY 1974

UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

AERO-MECHANICAL ENGINEERING
LABORATORY

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At the request of the United States Army Natick Research and Development Command, (NARADCOM) the Center for Building Technology conducted solar heat load tests on five sections of M.U.S.T. air-inflatable, double-wall hospital ward shelters. The purpose of the test was to evaluate the effect of solar heat load, as simulated by infrared heat lamps, on various materials and construction designs proposed for use in the shelters.

This report summarizes the results of the tests.

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PREFACE

This report was prepared by the Center for Building Technology, National Bureau of Standards (NBS) under Project Order STSNLD 74-133 to NBS, Production Engineering for OPA funded items M.U.S.T. shelters. The work was carried out under the direction of project managers Dr. Constantin J. Monego and Mr. Albert A. Carletti of the US Army Natick Research and Development Command (NARADCOM). NARADCOM has also been known as the "US Army Natick Laboratories (NLABS)" and "US Army Natick Development Center (NDC)

SI Conversion Units

In view of the present accepted practice in this country for building technology, common US units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, assistance is given to the reader interested in making use of the coherent system of SI units by giving converion factors applicable to US units used in this paper.

Length

1 in = 0.0254 meter (exactly)

1 ft = 0.3048 meter (exactly)

Force

1 lb (lbf) = 4.448 Newtons (N)

Pressure

1 psf = 47.88 N/m^2

1 psi = 4894 N/m^2

Temperature °C – 5/9 (Temperature °F – 32)

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1. Introduction

1.1 Objective

At the request of the United States Army Natick Research and Development Command (NARADCOM), the Center for Building Technology (CBT) of the National Bureau of Standards conducted solar heat load tests on five sections of M.U.S.T. (Medical Unit, Self-Contained, Transportable) air-inflatable, double-wall hospital ward shelters. The purpose of the tests was to evaluate the effect of solar heat load, as simulated by infrared heat lamps, on various materials and construction designs proposed for use in the shelters.

The need for the tests resulted from various failures which occurred when shelters purchased by NARADCOM were erected in the field. Three types of observed failures were particularly important to the performance of the shelters. The first type of observed failure in field erected shelters was tearing or pulling of the exterior fabric near the air inlet valve assembly. The second was tearing of the webbing material between the individual air-inflated bladder chambers. The third was delaminations of the adhesively bonded strapping material which covered the exterior sewn seams.

To prevent these failures in future shelters, new techniques were proposed for joining the exterior fabric to the valve assembly and for sewing the webbing, and new adhesives were considered for bonding the fabric. The five sections which were tested contained various construction designs and materials so that their usefulness could be determined.

1.2 Description of Shelters

Each air-inflatable, double-wall hospital ward shelter section which was evaluated consisted of either 12 or 13 individual semi-cylindrical chambers approximately 20 in. in diameter and 35 ft in length. The dimensions of an erected shelter section measured approximately 24 ft. in width, 12 ft., in height, and 14 ft. in length. Figure 1 is a picutre of one of the erected shelter sections. Shelter sections are designed to be joined together to form a shelter of the desired size.

The shelter sections were to conform to NARADCOM Purchase Descriptions except for changes agreed to by NARADCOM. According to NARADCOMS information, the exterior skin of the shelter sections consisted of polyester fabric coated on the interior with black neoprene and on the exterior with black neoprene, olive green neoprene and olive green hypalon. The interior skin of the shelter sections consisted of polyester fabric

coated on one side only with black neoprene, pale green neoprene, and pale green hypalon. The result of this is that the entire exposed exterior surface was olive green hypalon and the entire exposed interior surface was pale green hypalon.

The interior and exterior skins were joined by coated cloth webs which were sewn to each skin, thus forming the individual semi-cylindrical chambers. The cloth webs were fabricated from polyester cloth. An air-inflatable bladder, placed inside each semi-cylindrical chamber, was fabricated from nylon cloth, coated on one side with neoprene.

Each semi-cylindrical chamber and bladder was equipped with an air inlet valve and an air pressure release valve designed to prevent over-pressurization. Figure 2 shows the location of the air inlet valve assemblies on one of the shelter sections. Figure 3 is a closeup of an air inlet valve. The pressure relief valves were located in about 7 in. below each air inlet valve. Upon erection, each bladder was designed to contain an air pressure of approximately 1.5 psi.

2. Test Specimens

The five shelter sections which were tested were supplied by the NARADCOM. Two of the sections were fabricated by manufacturer F and three by manufacturer IP. In this report, the shelter sections will be designed as F-1, F-2, IP-1, IP-2, and IP-3.

The serial numbers of the tested shelter sections are as follows:

Shelter Section Number	Serial Number
F-1	SO57
F-2	SO57
IP-1	S-1
IP-2	S-2
IP-3	S-3

Shelter sections IP-1, IP-2, and IP-3 were corridor connectors which were constructed according to NARADCOMS Limited Production Purchase Description LP/P DES 39-70 (26 August 1970) except for the changes listed in Tables 1 through 3 respectively. The corridor connector shelter sections contained a doorway on each side of the section as shown in Figure 1. Shelter sections F-1 and F-2, which were not corridor connectors, were constructed according to NARADCOMS Limited Production Purchase Description LP/P DES 42-70 (1 September 1970) except for the changes listed in Tables 4 and 5.

One additional shelter section, which was a production line fabricated by manufacturer IP according to NARADCOMS Limited Production Purchase Description LP/P DES 39-70

(26 August 1970), was tested to calibrate the test apparatus. This shelter section was also used to determine if the test procedure induced failures similar to those observed in field erected shelter sections.

3. Test Apparatus and Procedure

3.1 Test Apparatus for Inducing Solar Heat Load

The test apparatus for inducing the solar heat load consisted of 388 infrared heat lamps attached to a 180° archway. The archway was approximately 15 ft. in length and 30 ft. in diameter and the shelter sections were erected inside the archway for test. The distance from the surface of the infrared lamps to the exterior surface of the shelter sections was approximately 2.5 ft. The test apparatus and the position of a shelter section to be tested are shown in Figure 1.

Rheostats, which regulated the amperage of approximately 30 lamps each, were installed to permit adjustment of the surface temperature of each shelter section to the desired level.

3.2 Location of Thermocouples

Twenty-one thermocouples were used to measure the surface temperature of shelter sections F-1 and F-2 while 22 were used for shelter sections IP-1, IP-2, and IP-3. The exterior surface thermocouple locations for the sections fabricated by manufacturers F and IP are shown in Figures 4 and 5, respectively.

In Figures 4 and 5, each thermocouple is described by a series of letters and numbers. The meaning of the letters is as follows:

T – thermocouples designated with a T were installed on the exterior surface of the shelter section at the crest of the semi-cylindrical chamber.

S – thermocouples designated with an S were installed on the exterior surface of the shelter section directly above the sewn seams.

The number immediately following the letter or letters is the number of each semi-cylindrical chamber in the test section. The numbering system is from left to right when facing a shelter section from the manifold side. The next number in the series is the distance in feet from the center of the air valve to the thermocouple Thus the thermocouple designated T2-3 was located at the crest of the exterior surface of air chamber number 2 and was 3 feet from the center of the air inlet valve.

One thermocouple was also installed on the interior surface of each shelter section. This thermocouple was located directly opposite thermocouple T7-18 on sections F-1 and F-2 and opposite thermocouple T7-7 on sections IP-1, IP-2 and IP-3.

In addition, one or two thermocouples were used to measure the ambient air temperature inside the shelter section during the test.

Thermocouples installed on the surface of the shelter sections were held in place by sandwiching them between the fabric of the shelter and a small piece of the same fabric. The two layers of fabric were joined using Eastman 910 adhesive.

3.3 Use of Thermographics to Verify Thermocouple Readings

The NBS thermographics system was used to determine the uniformity of the temperature distribution over a portion of the exterior surface of shelter section IP-1 and to verify the temperatures recorded from thermocouple readings.

The thermographics system consisted of an infrared television camera and television receivers that display, in real time, thermal images upon sensing natural infrared radiation emitting from the surface of an object.

The infrared camera was aimed at an area of the shelter section which included thermocouples T1-3, T2-3, and T3-3.

A temperature graph, Figure 6, was obtained. Also, a color-coded thermograph was obtained. The thermograph is not included because of the difficulty in reproducing the colors.

The location of each thermocouple on the curve of Figure 6 was determined and the temperature as read in Figure 6 compared with the thermocouple readings.

The comparisons are as follows:

Thermocouple Number	Temperature, °F	
	Thermocouple	Thermographic System
T1-3	177.2	184.4
T2-3	194.5	188.0
T3-3	191.4	190.0

3.4 Installation of Manometers

Manometers were used to provide a continuous measure of the air pressure in each air inflatable bladder. The manometer installation consisted of drilling a small hole through the air inlet valve assembly, inserting a plastic tube in the hole, and connecting the plastic tube to manometer gauges. The plastic tube, as inserted in the air inlet valve, can be observed in Figure 4.

3.5 Monitoring of Pressure Relief Valves

Selected pressure relief valves, which were included on each air inflatable chamber, were monitored during the tests of all shelters. The relief valves were designed to function at 1.75 ± 0.25 psi. Figure 7 shows the monitors for the pressure relief valves of shelter section F-2.

The primary purpose of monitoring the pressure relief valves was to determine if they did function properly within the design limits.

The monitoring consisted of passing air escaping from the relief valves into beakers of water and visually observing the relief valves into beakers of water and visually observing the extent of bubbling.

The extent of the bubbling in each pressure relief valve monitor was observed periodically and classified as one of the following: none, slight, light, medium, or heavy.

3.6 Test Procedure

Each shelter section to be tested was placed under the archway containing the infrared heat lamps. Following the installation of the exterior surface thermocouples, manometers, and relief valve monitors, the shelter section was erected by inflating it to approximately 1.5 psi. The shelter section was leak-tested overnight before being reinflated to 1.5 psi (shelter section F-1 was leak tested for four hours rather than overnight). All leak tests were conducted at an ambient temperature of approximately 70°F.

The sonar heat load test, which then was started, consisted of increasing the exterior surface temperature of the shelter section to 200°F. The increase in temperature from ambient to 200°F was designed to take about 2 hours. The temperature was maintained at 200°F for four hours and was then decreased over a two-hour period to ambient. The eight-hour procedure described above was then repeated the following day so that each shelter section was subjected to two simulated solar heating cycles. The ambient air temperature was controlled during the tests to permit personnel to periodically inspect the monitors of the pressure relief valves as well as imspect the shelter section materials during the tests.

The solar heat load test procedure, which was specified by NARADCOM was similar to the procedure reported in test method 505 of the Military Standard 810B, "Environmental Test Methods", June 15, 1967.

Periodic recordings were made, during the test, of thermocouple readings, manometer readings, and the extent of bubbling observed from the pressure relief valve monitors.

During each solar heat load cycle, the pressure inside the bladders decreased due to slow leakage. Additional air was not added to shelter section F-1 during the first cycle test, but during the second cycle and during tests of all other shelter sections, additional air was added several times to reinflate the sections to approximately 1.5 psi. Thus, for practical purposes, the chambers remained stressed during all tests except the first cycle of shelter F-1.

Thermocouples installed on the exterior surface at the crest of the semi-cylindrical chambers were used to determine when the exterior surface temperature was 200°F. Temperatures on the surface of the strapping, which covered the sewn seams, were observed to be 25-30°F less than that at the crest. The reason for the temperature differential is that the strapping was farther from the heat lamps than was the crest due to the corrugated appearance of the surface.

Prior to commencing the tests of shelter sections F-1, F-2, IP-1, IP-2, and IP-3, the solar heat load test procedure was conducted on a production line shelter section, fabricated by manufacturers IP according to NARADCOMS Limited Production Purchase Description LP/P DES 39-70 (26 August 1970). The purposes of this test were to calibrate the test apparatus and to determine if the test procedure induced failures similar to those observed in field erected shelter sections. Following this preliminary test, the exterior fabric near the air inlet valve assemblies had torn extensively and more than 50% of the strapping had delaminated. Thus, the solar heat load test caused some of the same types of failure as had been observed on shelter sections erected in the field.

4. Test Results

4.1 F-1 Shelter Section

4.1.1 Leak Test

A leak test on shelter section F-1 was performed for four hours prior to starting the first solar heat load cycle. Table 6 shows the results of the leak test.

The bladder in air chamber 1 lost air very rapidly as can be noted in Table 6. Bladders in chambers 2, 3, 4, 10, and 11 showed a loss of air pressure to below 1.0 psi.

4.1.2 Solar Heat Load Test

The solar heat load test was conducted as described in Section 3.6.

Figure 8 contains a plot of data from three representative exterior surface thermocouples, one interior surface thermocouple, and one ambient air thermocouple during the first cycle of the test. The location of the exterior surface thermocouples can be noted in Figure 4. A plot of the thermocouple readings for the second test cycle is not included because of the similarity of readings obtained in the two cycles.

Table 7 contains representative manometer data in psi for the first test cycle of shelter section F-1. Air pressure measurements are included for each of the twelve air inflatable bladders at various times from the start of the test. The monitors for the pressure relief valves were not installed during the first test cycle of shelter section F-1. The test section was not reinflated during this test cycle.

Table 8 summarizes the manometer data and observations of the three pressure relief valve monitors during the second test cycle of shelter section F-1. During the second test cycle, the shelter section was reinflated to approximately 1.5 psi at the following times from the start of the test (hours: minutes): 2:45, 4:10, 4:40, 5:10, 5:15, 6:20, 6:40, 6:55, 7:05, 7:25 and 7:50. The reinflation times are shown by the dashed vertical lines on Table 8.

4.1.3 Observations

The bladder in air chamber 1 lost air rapidly during the leak test and during the solar heat load test. As evidenced by the data in tables 6 through 8, this bladder deflated much more rapidly than the other eleven.

Following the completion of the solar heat load test, the bladder in air chamber 1 was removed from the shelter section and inflated to determine the reason for the excessive leakage. The only source of the leakage was near the air inlet valve.

The strapping material prior to the test was observed to form some "tunneled" areas directly above the seams. "Tunneled" areas were areas in which the strapping was bonded on both sides but not in the middle. Strapping which was well bonded in the seam crease was evidenced by the stitching imprint through the strapping.

Observations relating to debonding of the strapping following the first cycle of the solar heat load test are summarized in Table 9. Debonding primarily occured at the points of diagonal cuts in the strapping and near the edge of strapping. The tunnels described above were also observed to expand in length and width.

The debonding of the strapping did not increase substantially in the second cycle of the test.

The fabric around all air inlet valves remained intact following the test and no webbing failures were observed.

4.2 F-2 Shelter Section

4.2.1 Leak Test

A leak test on shelter section F-2 was performed for 15.5 hours prior to starting the first solar heat load cycle. Table 10 contains the results of the leak test. The air pressure in bladders 10, 11, and 12 decreased to < 0.21 psi at the end of 15.5 hours while other bladders retained substantially more air pressure.

4.2.2 Solar Heat Load Test

The solar heat load test was conducted on shelter section F-2 as described in Section 3.6.

Figure 9 contains a plot of data from three representative exterior surface thermocouples, one interior surface thermocouple, and one ambient air thermocouple during the first cycle of the test. The location of the exterior surface thermocouples can be noted in Figure 4. A plot of the thermocouple readings for the second test cycle is not included because of the similarity of the readings obtained in the two cycles.

Tables 11 and 12 summarize the manometer data and observations of the twelve pressure relief valve monitors during the first an; second test cycles, respectively.

During cycle 1 of the test, the shelter section was reinflated at the following times from the start of the test (hours:minutes): 2:55, 5:15, and 6:40. The shelter section was reinflated during the second cycle at the following times from the start of the test (hours:minutes): 4:10, 5:57, 6:10, 6:50, 7:35, and 7:42. These reinflation times are shown by the dashed vertical lines on Tables 11 and 12.

4.2.3 Observations

The bladder in air chamber 1 ruptured about 2 hours after commencing the first test cycle. Figure 10 shows the erected shelter section following the deflation of bladder 1. The bladder in air chamber 10 lost air rapidly due to leakage during the first test cycle. At the completion of thy first test cycle, the bladders in air chambers 1 and 10 were removed for inspection. Bladder 1 had ruptured at an adhesive bond. The

fabric on either side of the rupture was well bonded. The failure is shown in Figures 11 and 12. The rupture was about 7 in. in length. Bladder 10 was leak tested and the only obserable leak was near the air inlet valve. The bladders which were removed from air chambers 1 and 10 were replaced by the bladders from air chambers 6 and 5 respectively of shelter section F-1 prior to conducting the second test cycle.

The strapping on seam 8 showed slight tunneling (2" in length), before testing about 9 ft. from the ground on the side opposite the valves. During the first cycle, the tunneling extended to about 4" in length. This tunneling was located at an area of excess stress due to crooked stitching as shown in Figure 13. The tunneling did not extend farther during the second test cycle.

Several other strappings were initially observed to exhibit tunneling. Tunnels of 1/4" widened during the first test cycle to 1/2" or more while those less than 1/4" widened to somewhat less than 1/2" at the end of the first cycle. The tunnels did not appear to widen further in the second test cycle.

The fabric comprising the air inlet valve ring collar was observed to pull or slip slightly from the original location on all 12 air chambers. This fabric slippage was primarily on the sides rather than at the top and bottom. The slippage on the collar of air chamber 12 was about 3/32" while other slippage ranged from 1/13" to 1/18". Figure 14 shows the fabric slippage for the collars of air chambers 11 and 12. The picture in Figure 14 was taken following the second test cycle but most of the slippage occurred during the first test cycle.

Slight delaminations of some valve ring collars were also observed at the completion of the first test cycle. The delaminations were noted on the collars of air chambers 7, 8, 9, 10, 11 and 12. Figure 15 contains a picture of the delamination at air chambers 11 and 12. The delaminations were not greater than 1/2" in width and 1" in depth and they did not extend farther during the second test cycle. One screw hole in the collar of air chamber 2 also pulled out during the first test cycle. The movement was about 1/2".

Several adhesive bonded patches on one side of the interior of the shelter section had delaminations during the first test cycle. The air chamber numbers, number of delaminated patches and total number of patches are as follows:

Air Chamber Number	Number of Delaminated Patches	Total Number of Patches on the Air Chamber
1	0	4
2	3	11
3	1	4
4	1	4
5	2	11
6	0	4
7	1	4
8	0	11
9	0	4
10	0	4
11	0	11
12	0	4

The interior patch delaminations varied from 10% to 30% of the bonded surface areas. The delaminations did not appear to increase during the second test cycle.

One additional observation was that occasionally the exterior fabric near a sewn seam was wrinkled as shown in Figure 16 for seam 9. The wrinkling leads to difficulty in bonding the strapping and edge lifts and tunneling were commonly observed at these locations.

The pressure relief valves on air chamber 7 and 10 did not relieve during the second test cycle as can be noted in Table 12. Following the completion of the second test cycle, the shelter section was slowly inflated to determine the pressure necessary to relieve the two valves. Relief valve 7 relieved at 2.05 psi while valve 10 relieved at 2.57 psi. During the second test cycle, the air pressure in chamber 7 reached as high as 2.26 psi without relief of the valve.

4.3 IP-1 Shelter Section

4.3.1 Leak test

A leak test on shelter section IP-1 was performed for 15 hours prior to starting the first solar heat load cycle. Table 13 contains the results of the leak test.

The air pressure in bladders 2, 3, 5, 6, 7, 8, and 9 decreased to < 0.21 psi at the end of 15 hours.

4.3.2 Solar Heat Load Test

The solar heat load test was conducted on shelter section IP-1 as described in Section 3.6.

Figure 17 contains a plot of data from three representative exterior surface thermocouples, one interior surface thermocouple, and one ambient air thermocouple during the first cycle of the test. The location of the exterior surface thermocouples can be noted in Figure 5.

Tables 14 and 15 summarize the manometer data and observations of the six pressure relief valve monitors during the first and second test cycles respectively.

During cycle 1 of the test, the shelter section was reinflated at the following times from the start of the test (hours:minutes): 3:50, 5:10, 6:20, 6:40, 7:30, 7:43, and 8:04. The shelter section was reinflated during the second cycle at the following times from the start of the test (hours:minutes): 3:25, 4:20, 5:50, 6:25, 6:53, and 7:40. These reinflation times are shown by the dashed vertical lines on Tables 14 and 15.

4.3.3 Observations

The strapping over the sewn seams in shelter section IP-1 was well bonded prior to the start of the test as evidenced by the visually observable imprint of stitches through the strapping. Following the two test cycles, no strapping failures were observed. Also, no fabric failures were observed near the air inlet valves or in the webbing following the test.

During the second test cycle, a bonded joint on the fabric comprising the air intake manifold to air chambers 5-9 pulled apart about 6" from the shelter section surface. The failure was a cohesive separation within the adhesive.

At the completion of the second test cycle, NARADCOMS personnel determined that the exterior fabric contained a hypalon coating but no black neoprene coating on the face side of the base fabric.

A test was run following the solar heat load test to determine the pressure required to relieve pressure relief valves 12 and 13. Valve 12 relieved at 2.21 psi and valve 13 relieved at 2.14 psi.

4.4 IP-2 Shelter Section

4.4.1 Leak test

A leak test on shelter section IP-2 was performed for 22 hours prior to starting the first solar heat load cycle. Table 16 contains the results of the leak test.

The air pressure in bladders 1, 5, 6, 7, 8, 9, 12 and 13 decreased to < 0.21 psi at the end of 22 hours.

4.4.2 Solar Heat Load Test

The solar heat load test was conducted on shelter section IP-2 as described in Section 3.6.

Figure 18 contains a plot of data from three representative exterior surface thermocouples, one interior surface thermocouple, and one ambient air thermocouple during the first cycle of the test. The location of the exterior surface thermocouples can be noted in Figure 5.

Table 17 and 18 summarize the manometer data and observations of the eight pressure relief valve monitors during the first and second test cycles respectively.

During cycle 1 of the test, the shelter section was reinflated at the following times from the start of the test (hours:minutes): 4:14, 6:20, 6:45, and 7:23. The shelter section was reinflated during the second cycle at the following times from the start of the test (hours:minutes): 3:55, 5:05, 6:35, 6:48, and 7:48. These reinflation times are shown by the dashed vertical lines on Tables 17 and 18.

4.4.3 Observations

The strapping over the sewn seams in shelter section IP-2 was well bonded prior to the start of the test as evidenced by the visually observable imprint of stitches through the strapping. Small tunnels, about 2" long and 1/4" wide, formed in two places on two strappings during the test. However, the strapping generally looked very good following the test.

Also, no fabric failures were observed near the air inlet valves or in the webbing.

At the end of the second test cycle, the adhesive bond joining the sides of the shelter section to the floor was delaminated directly below air chamber 1. This delamination in shown in Figure 19.

The bladder in air chamber 1 would not deflate completely at the and of the test. Tha reason for this problem was that the excess bladder was compressed near the air inlat valve. Figure 20 shows the excess bladdar which was pulled from tne air chamber. The bladder in air chamber 1 was the only bladder removed for inspection.

The exterior fabric of shelter section IP-2 was determined to contain a hypalon coating but no black neoprene coating on the face si. of the base fabric.

4.5 IP-3 Shelter Section

4.5.1 Leak Test

A leak test was performed on shelter section IP-3 for 15.5 hours prior to starting the first solar heat load cycle. Table 19 contains the results of the leak test.

The bladders of this shelter section retained air better than any of the other four sections tested. The lowest air pressure measured following the overnight leak test was 0.45 psi in bladder 6.

4.5.2 Solar Heat Load Test

The solar heat load test was conducted on shelter section IP-3 as described in Section 3.6.

Figure 21 contains a plot of data from three representative exterior surface thermocouples, one interior surface thermocouple, and one ambient air thermocouple during the first cycle of the test. The location of the exterior surface thermocouples can be noted in Figure 5.

Tables 20 and 21 summarize the manometer data and observations of the seven pressure relief valve monitors during the first and second test cycles respectively.

During cycle 1 of the test, the shelter section was reinflated at the following times from the start of the test (hours:minutes): 6:13, 6:48, and 7:33. The shelter section was reinflated during the second cycle at the following times from the start of the test (hours:minutes): 6:23 and 7:50. These reinflation times are shown by the dashed vertical lines on Tables 20 and 21.

4.5.3 Observations

The strapping over the sewn seams in the shelter section IP-3 was well bonded prior to the start of the test as evidenced by the visually observable imprint of the stitches through the strapping. No strapping failures were observed as a result of the solar heat load test.

Also, no fabric failures were observed near the air inlet valve or in the webbing.

The exterior fabric of shelter section IP-3 was determined to contain a hypalon coating but no black neoprene coating on the face side of the base fabric.

5. Summary

A. Indication that solar heat load test induces failures similar to those observed in field erected shelter sections.

Prior to commencing the tests of shelter sections F-1, F-2, IP-1, IP-2, and IP-3, the solar heat load test procedure was conducted on a production line shelter section, fabricated by manufacturer IP. The failures observed on this shelter section were very similar to those observed in field erected shelter sections.

B. Air inlet valve assemblies

(1) The exterior fabric, which was bonded to the air inlet valve assemblies, remained well bonded during the tests with the exception of the observations of shelter section F-2.

(2) The air inlet valve ring collars on all 12 air chambers of shelter section F-2 were observed to slip somewhat during the solar heat load tests and slight delaminations of the ring collars were observed on air chambers 7 through 12.

(3) The exterior fabric joined to the air inlet valve assembly on air chamber 2 of shelter section F-2 was observed to pull out about 1/2" at one screw hole.

(4) The bladders in air chamber 1 of shelter section F-1 and air chamber 10 of shelter section F-2 exhibited leakage near the air inlet valve assembly.

C. Webbing between air chambers

The coated cloth webs, used to form the sides of the indiviual air chambers, exhibited no failure during the tests of the five shelter sections.

D. Strapping covering the sewn exterior seams

(1) The strapping on shelter sections F-1 and F-2 was not as tightly fitted into the seam creases as was the strapping on shelter sections IP-1, IP-2, and IP-3.

(2) The "tunnels", formed by strapping which was not well fitted into the seam creases, extended in lenght and width during the solar heat load tests.

(3) The strapping on shelter section F-1 exhitited some delamination near the edges of the strapping and also at the points of diagonal cuts in the strapping.

(4) Strapping failures could often be related to excessive wrinkling of the exterior fabric near the sewn seams or excessive stress developed at the seam due to crooked seams.

E. Various other adhesive bond failures

(1) The bladder in air chamber 1 of shelter section F-2 ruptured during the first solar heat load cycle due to an adhesive bond failure between the bonded fabrics.

(2) Eight of the 34 adhesively bonded patches on one side of the interior surface of air chambers 2, 3, 4, 5, and 7 on shelter section F-2, exhibited delamination of 10%--30% during the solar heat load test. Since all the delaminated patches were located on one side of the shelter section, this may have been due to fabrication technique.

(3) A bonded fabric joint on the air intake manifold of shelter section IP-1 failed cohesively during the second test cycle.

(4) The adhesive bond between the valve side and the floor of shelter section IP-2 failed directly below air chamber 1 during the solar heat load test.

F. Pressure relief valves

Of the 68 pressure relief valves monitored during the tests, 8 did not relieve at pressures of less than 2.0 psi.

G. Effect of two solar heat load test cycles

The failures which were observed occurred during the first solar heat load cycle and did not increase substantially during the second cycle.

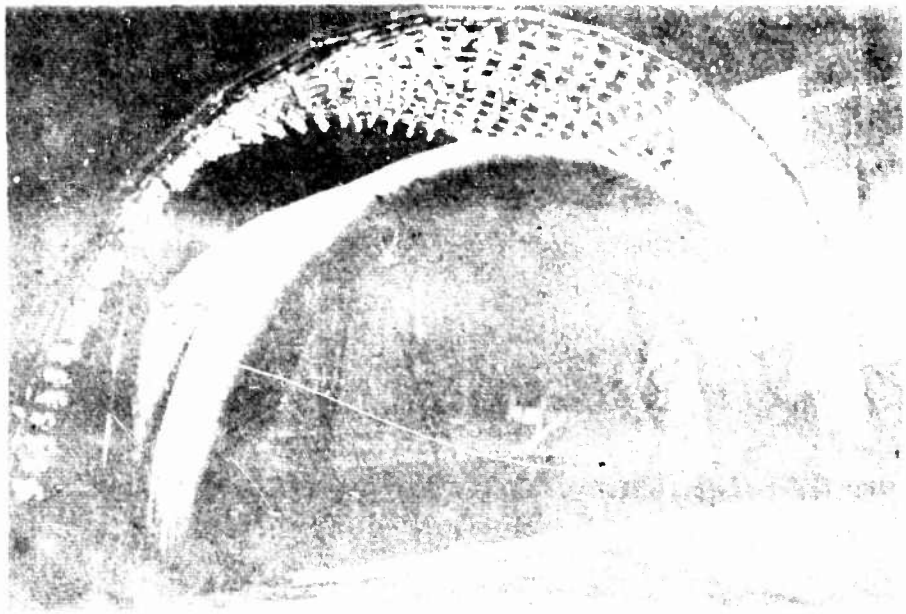

Figure 1. Shelter Section Undergoing Simulated Heat Load Test

Figure 2. Location of Air Inlet Valve Assemblies on Shelter Section Fabricated by Manufacturer F

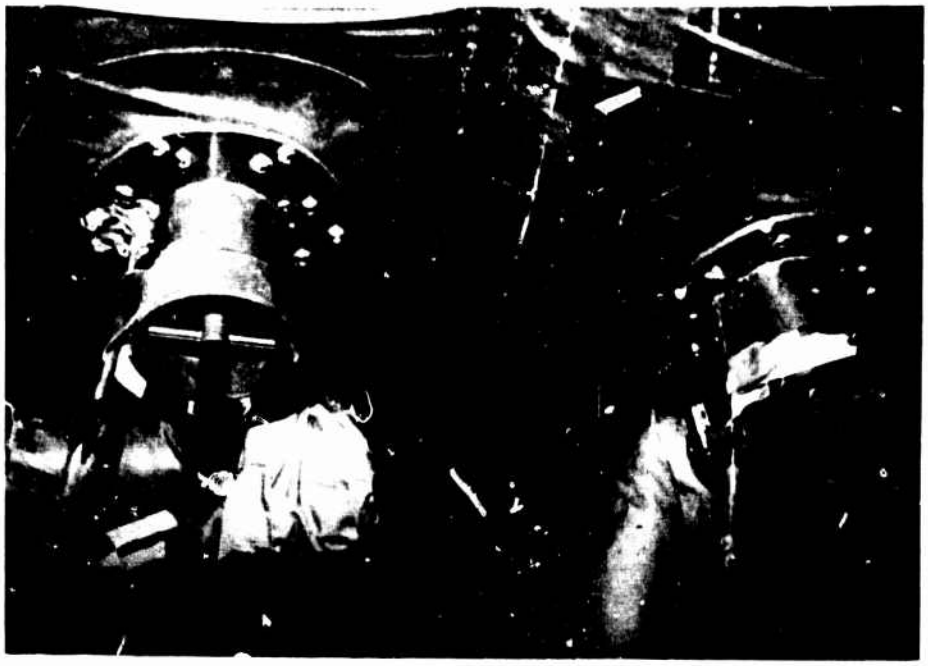

Figure 3. Exterior Appearance of an Air Inlet Valve Assembly

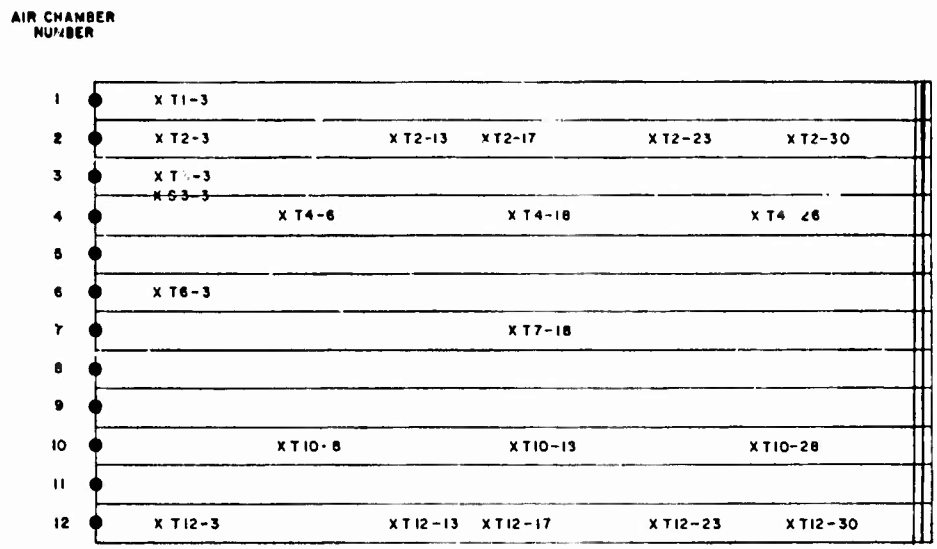

Figure 4. Location of Exterior Surface Thermocouples on Shelter Sections Fabricated by Manufacturer F

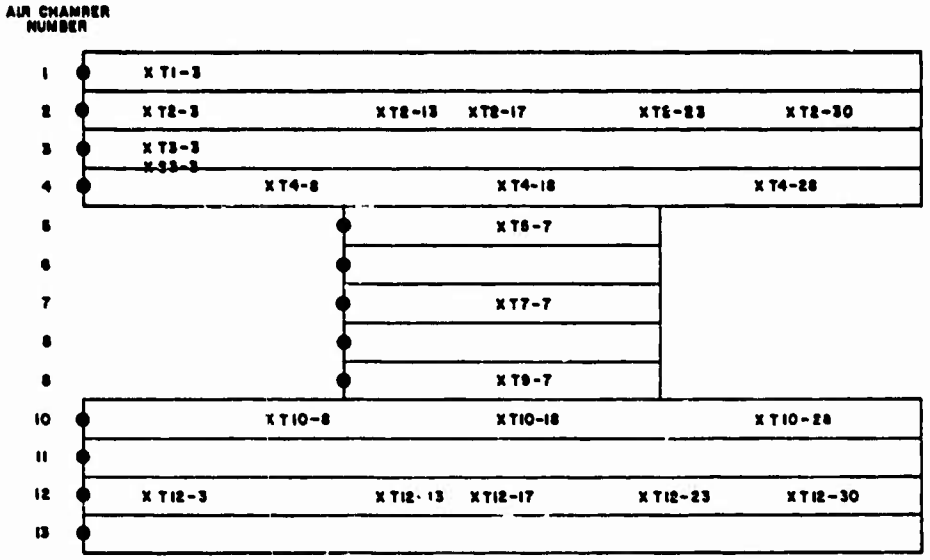

Figure 5. Location of Exterior Surface Thermocouples on Shelter Sections Fabricated by Manufacturer IP

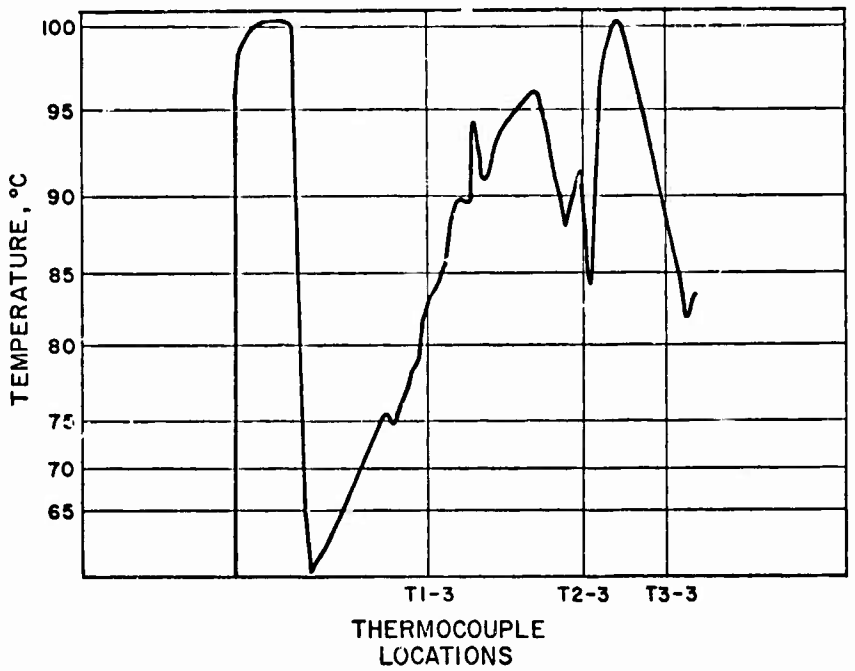

Figure 6. Temperature Graph Obtained by the Thermographics System

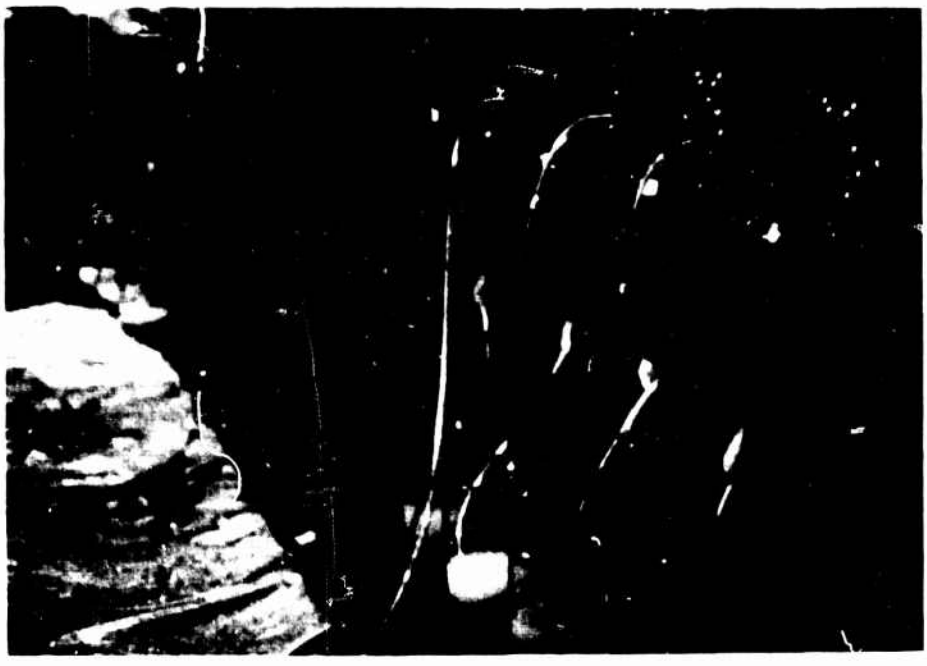

Figure 7. Pressure Relief Valve Monitors

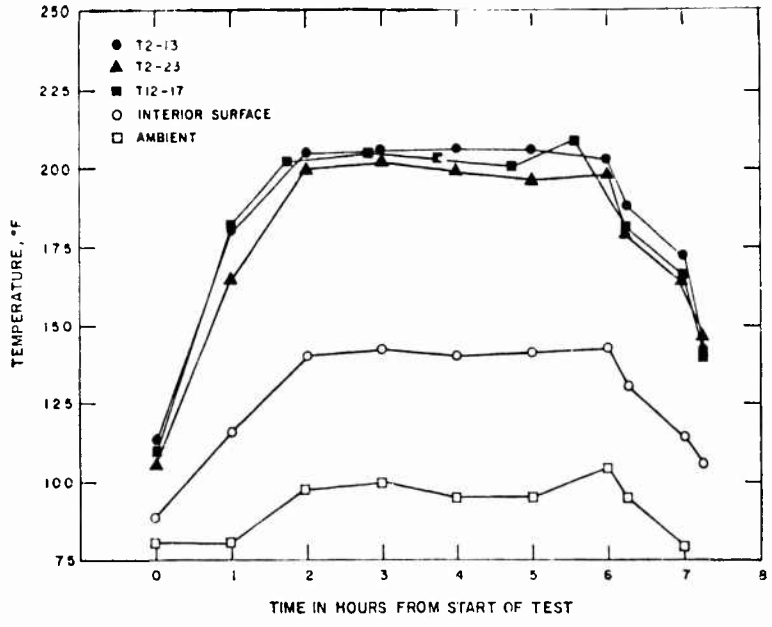

Figure 8. Temperature Readings of Selected Thermocouples During the First Cycle of Shelter Section F-1

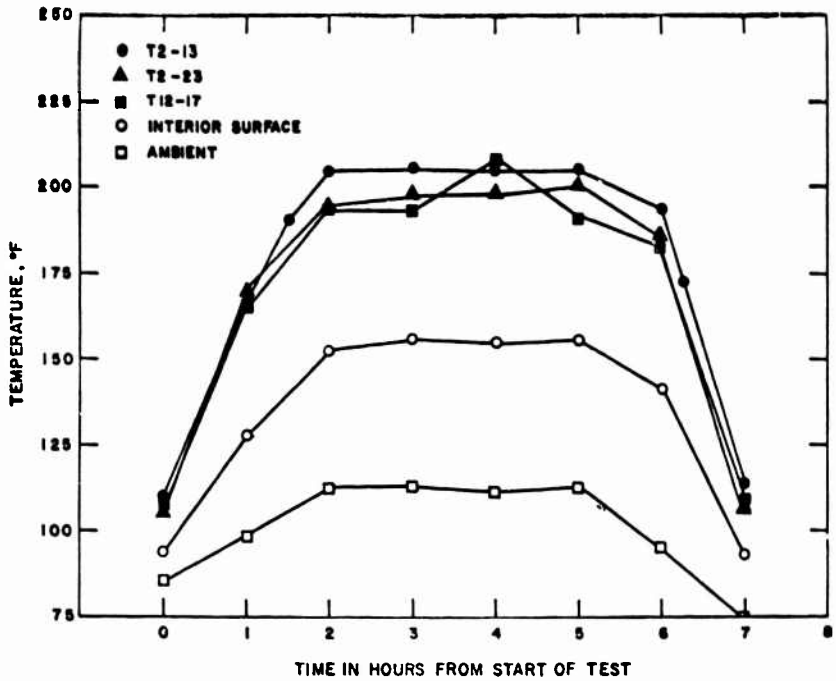

Figure 9. Temperature Readings of Selected Thermocouples During the First Cycle of Shelter Section F-2

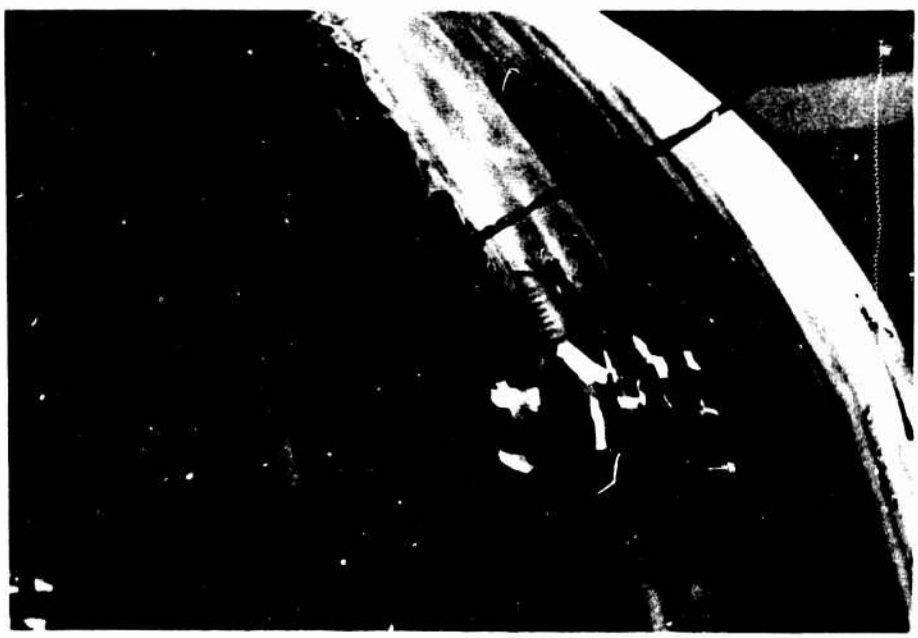

Figure 10. Erected Shelter Section F-2 Following the Deflation of the Bladder in Air Chamber 1

Figure 11. Ruptured Bladder after Removal from Air Chamber 1 of Shelter Section F-2

Figure 12. Close-Up of Bladder Failure after Removing the Bladder from Air Chamber 1 of Shelter Section F-2

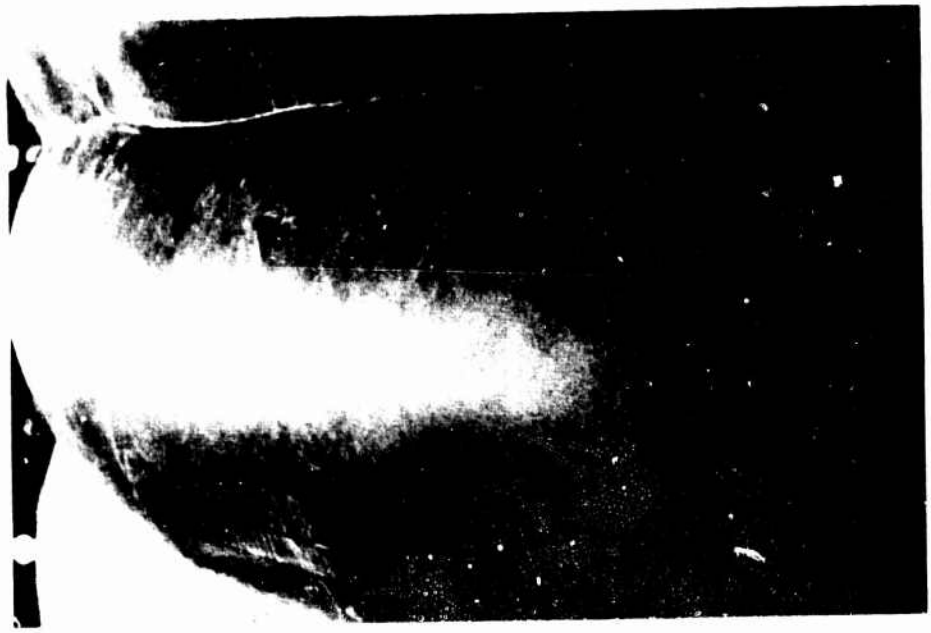

Figure 13. Stressed Seam Due to Crooked Stitching, Seam #8, Shelter Section F-2

Figure 14. Air Inlet Valve Ring Collar Slippage on Air Chambers 11 and 12 of Shelter Section F-2

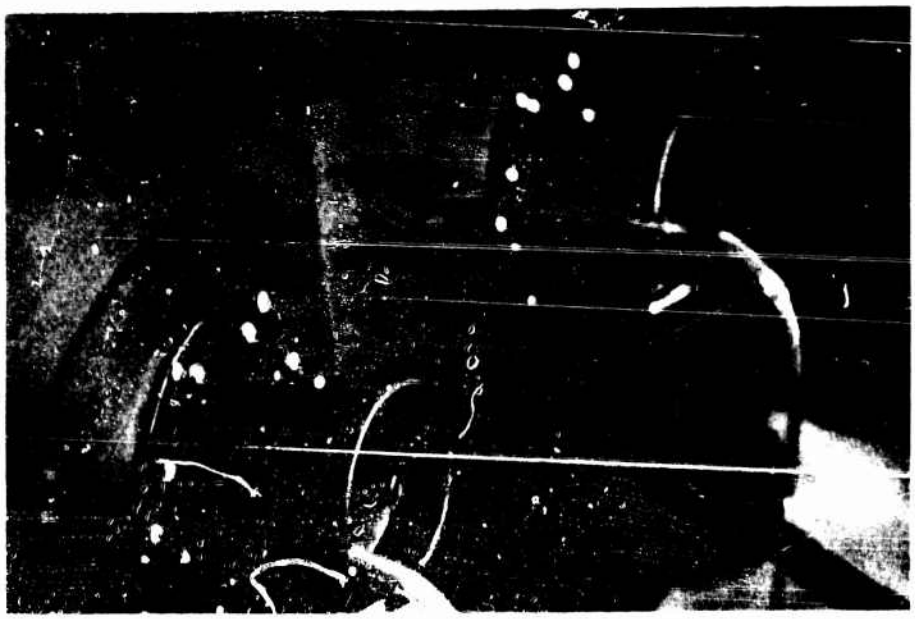

Figure 15. Air Inlet Valve Ring Collar Delaminated on Air Chambers 11 and 12 of Shelter Section F-2

Figure 16. Wrinkling of Exterior Fabric Near Seam #9 of Shelter Section F-2

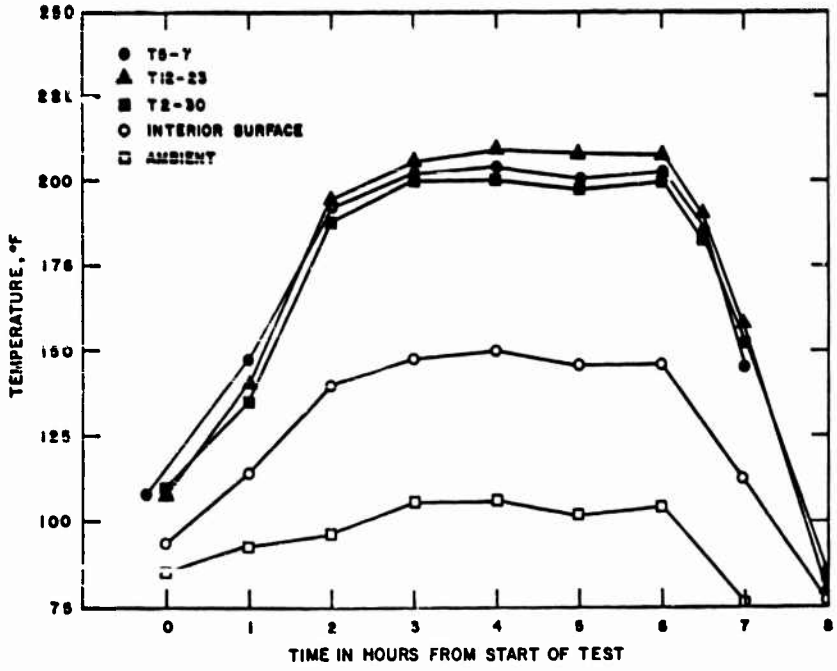

Figure 17. Temperature Readings of Selected Thermocouples During the First Cycle of Shelter Section IP-1

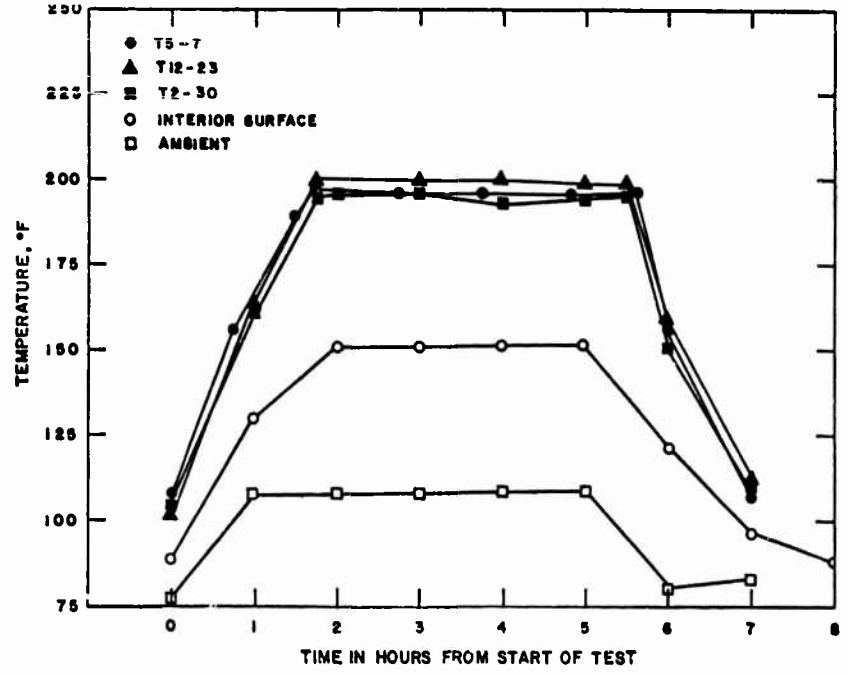

Figure 18. Temperature Readings of Selected Thermocouples During the First Cycle of Shelter Section IP-2

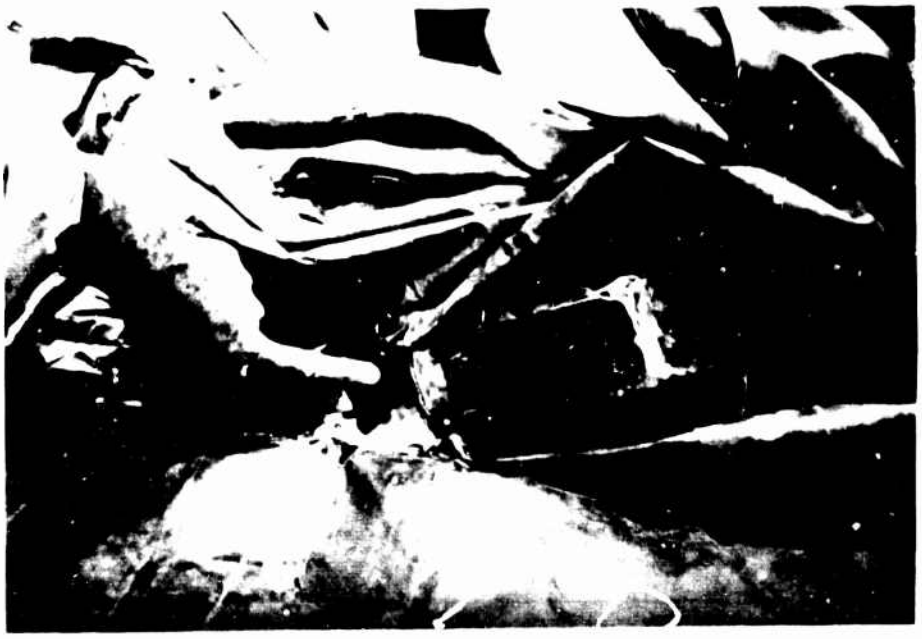

Figure 19. Delamination of Adhesive Bond Joining the Sides and Floor of Shelter Section IP-2

Figure 20. Excess Bladder Pulled from Air Chamber 1 of Shelter Section IP-2

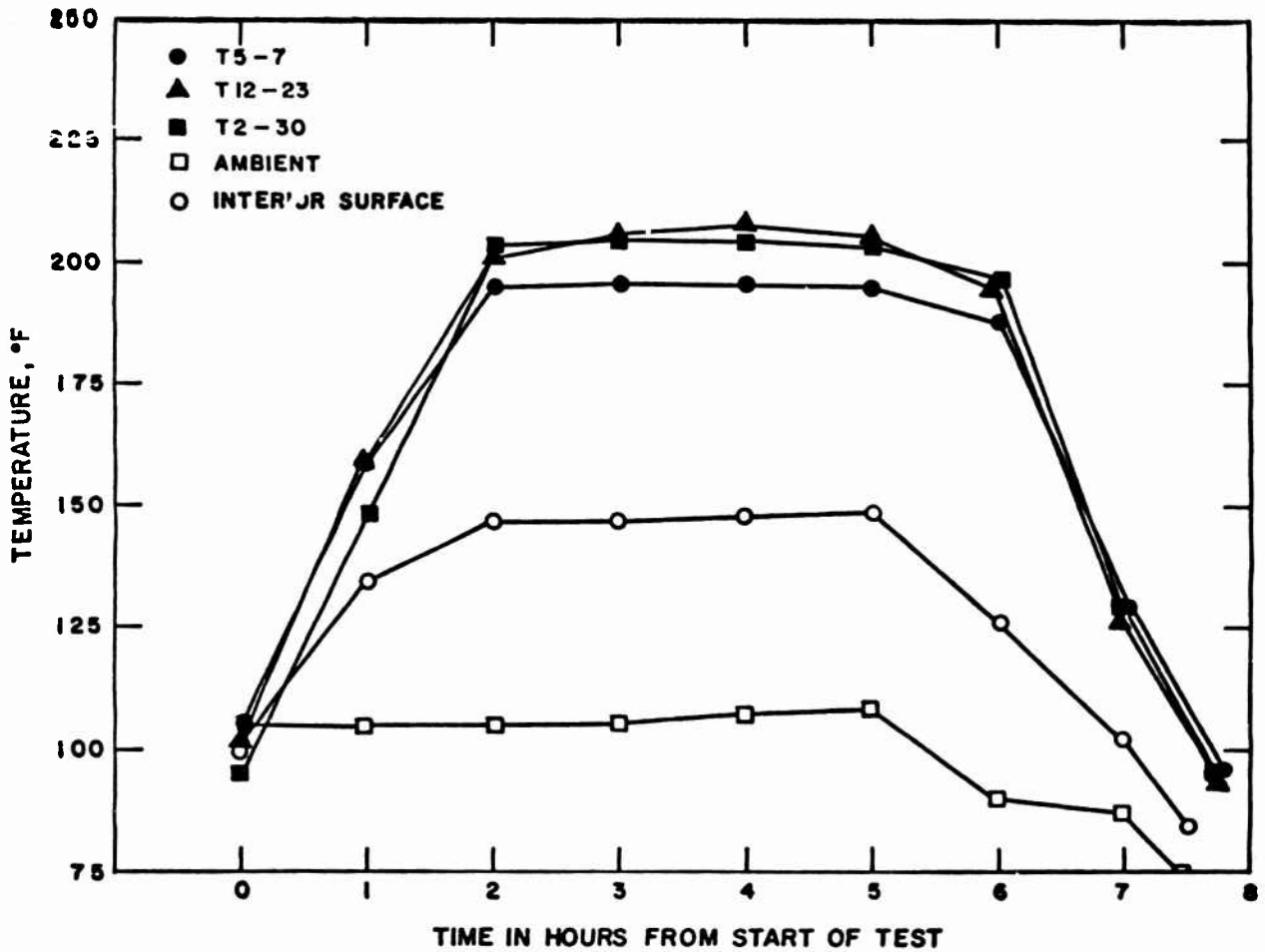

Figure 21. Temperature Readings of Selected Thermocouples During the First Cycle of Shelter Section IP-3

Table 1. Design Changes in Shelter Section IP-1 Relative to NARADCOM Limited Production Purchase Description LP/P DES 39-70 (26 August 1976)

1. Shelter section constructed with a web reinforcement of 2 1/2" using IP1018 adhesive for the web reinforcement; USM Chemical Bostik 1095 adhesive (1095) with USM Chemical Boscodur #9 accelerator (Boscodur #9) otherwise throughout, except as mentioned below.

2. Transition assembly bonded with USM Chemical Bostik 1039 adhesive (1039) with USM Chemical Boscodur #5 accelerator (Boscodur #5).

3. Transition assembly bonded to the shelter section enclosure with 1095 adhesive with Boscodur #9.

4. Corridor ground cloth assembly bonded with adhesive 1039 and Boscodur #5.

5. Transition floor assembly (Dwg No. 5-4-1411) bonded with adhesive 1039 and Boscodur #5.

6. Floor assembly entryway (Dwg No. 5-4-1512) bonded with adhesive 1039 and Boscodur #5.

7. Manifold assembly (Dwg No. 5-4-1530) bonded with adhesive 1039 and Boscodur #5.

8. Connector floor assembly (Dwg No. 5-4-1511) bonded with adhesive 1039 and Boscodur #5.

9. Shelter section walls bonded to the ground cloth with adhesive 1095 and Boscodur #9.

10. 1 oz. additional coating used on bladder material.

11. Zinc stearate used in all adhesive bonds in the shelter section.

Table 2. Design Changes in Shelter Section IP-2 Relative to NARADCOM Limited Production Purchase Description LP/P DES 39-70 (26 August 1970)

1. Shelter section constructed with a web reinforcement of 3 1/2" using 1018 adhesive for the web reinforcement; 1095 adhesive with Bosocodur #9 otherwise throughout, except as mentioned below.

2. Transition assembly bonded with 1095 adhesive and Boscodur #5.

3. Transition assembly bonded to the shelter section enclosure with 1095 adhesive and Boscodur #9.

4. Corridor ground cloth assembly bonded with 1039 adhesive and Boscodur #5.

5. Zinc stearate used in all adhesive bonds in the shelter section.

6. Transition floor assembly (Dwg No. 5-4-1411) bonded with 1039 adhesive and Boscodur #5.

7. Floor assembly entryway (Dwg No. 5-4-1512) bonded with 1039 adhesive and Boscodor #5.

8. Manifold assembly (Dwg No. 5-4-1530) bonded with 1039 adhesive and Boscodur #5.

9. Shelter section walls bonded to ground cloth with 1095 and Boscodur #9.

10. Connector floor assembly (Dwg No. 5-4-1511) bonded with 1039 adhesive and Boscodur #5.

11. 2 oz. additional coating used on bladder material.

Table 3. Design Changes in Shelter Section IP-3 Relative to NARADCOM Limited Production Purchase Description LP/P DES 39-70 (26 August 1976)

1. Shelter section constructed with a web reinforcement of 2 1/2" using 1018 adhesive for the web reinforcement.

2. Horizontal strapping of the outer cells bonded with 1039 adhesive and Boscodur #5.

3. Seam on air chamber #1 bonded with 1039 adhesive and Boscodur #5.

4. Stitching between air chambers #1 thru #6 bonded with 1039 adhesive and Boscodur #5.

5. Stitching between air chambers #7 thru #13 bonded with 1095 adhesive and Boscodur #5.

6. Transition assembly bonded with 1039 adhesive and Boscodur #5.

7. Transition assembly bonded to the shelter section enclosure with 1039 adhesive and Boscodur #5.

8. Corridor ground cloth assembly bonded with 1039 adhesive and Boscodur #5.

9. Zinc stearate used in all adhesive bonds in the shelter section, except as noted below.

10. 3-inch strapping on air chamber #1 with 1039 adhesive and Boscodur #5; no zinc stearate used.

11. Strapping between air chambers #1 and #2 bonded with 1039 adhesive and Boscodur #5; no zinc stearate used.

12. Strapping between air chambers #2 thru #6 bonded with 1039 adhesive and Boscodur #5.

13. 3-inch strapping on air chamber #13 bonded with 1095 adhesive and Boscodur #5; no zinc stearate used.

14. Strapping between air chambers #12 and #13 bonded with 1095 adhesive and Boscodur #5; no zinc stearate used.

15. Strapping between air chambers #7 thru #12 bonded with 1095 adhesive and Boscodur #5.

Table 3. Design Changes in Shelter Section IP-3 Relative to NARADCOM Limited Production Purchase Description LP/P DES 39-70 (26 August 1976) (cont'd)

16. Unit bonded to ground cloth with 1039 adhesive and Boscodur #5.

17. 1 oz additional coating used on bladder material.

18. Transition floor assembly (Dwg No. 5-4-1411) bonded with 1039 adhesive and Boscodur #5.

19. Floor assembly entryway (Dwg No. 5-4-1512) bonded with 1039 adhesive and Boscodur #5.

20. Manifold assembly (Dwg No. 5-4-1530) bonded with 1039 adhesive and Boscodur #5.

21. Connector floor assembly (Dwg No. 5-4-1511) bonded with 1039 adhesive and Boscodur #5.

22. A 1-inch diameter patch was bonded on inner casing panel just above the tie patch assembly.

Table 4. Design Changes in Shelter Section F-1 Relative to NARADCOM Limited Production Purchase Description LP/P DES 42-70 (1 September 1970)

1. Inflation valve rings on air chambers #1 thru #6 and #9 thru #12 were installed using design of manufacturer F. Inflation valve rings on air chambers #7 and #8 were installed using design of NARADCOM.

2. Webs #1 thru #6 have 9 regular size (per print) panels each plus two end pieces. Webs #7 thru #1 have 18 half-size web panels each. All webs have the 2"-wide bias tape bonded to the inner and outer radii using Firestone MAG-1265 adhesive coated side of tape to coated side of web.

3. All pressure relief valves have the 1.75 ± .25 psi springs installed.

4. Pressure relief valve collars are rubber discs.

5. All webs were sewn to the inner casing panels using Type 301 lockstitch.

6. Outer seams strapped as follows:

All seams have strappings as specified in LP/P DES 42-70 except web seams #1 and #2 which have a neoprene gum strip underneath the fabric strapping.

7. The ground cloth has the maximum of 4 transverse splices.

8. Adhesive 1039 and Boscodur #5 were used throughout the shelter except as otherwise noted above.

Table 6. Design Changes in Shelter Section F-2 Relative to NARADCOM Limited Production Purchase Description LP/P DES 42-70 (1 September 1970)

1. All inflation valve rings on the outer casing were installed utilizing design of manufacturer F. Rings on air chambers 1 thru 6 – installed with 1039-5 adhesive rings of air chambers 7 thru 12 – installed with F525441 adhesive.

2. Webs 1 thru 6 have triangular overlap splice on web panels. No bias tape. Webs 7 thru 11 have standard 1/2" lap splices on web panels and 2' wide bias tape bonded to inside and outside radii using 525441 adhesive, the coated side of tape to coated side of web.

3. All presure relief valves have the 1.75 ± .25 psi springs installed.

4. All pressure relief valve collars are of the fabric patch design in lieu of specified rubber disc. Each patch was installed using 52544 advesive.

5. All webs were sewn to the inner casing panels using Type 401 chain-stitch with the chain portion being exposed.

6. Outer seams strapped as follows:

A. 1 1/2" wide O.G./black fabric -- seams 1, 2, 3, 6, 7.

B. 1 1/2" wide O.D. Tedlar w/neoprene gum backing -- seams 5, 9, 10, 11 (also used on right end enclosure to outer casing feld seam).

C. 4" wide O.G./black fabric -- seams 4, 8

7. An acrylic coating compound was applied to the exposed chain portion of the chain stitch on web seams #1 and #1 to lock the stitch in place.

8. Ahdesive 1039 and Boscodur #5 were usec throughout the shelter except as otherwise noted above.

TABLE 6

Results of Four-Hour Leak Test on Shelter Section F-1

Air Chamber Number	Air Pressure (psi) at Specified Times in Hours from Start at Leak Test					
	0	0.5	1.0	2.0	3.0	4.0
1	1.60	0.77	0.36	–	–	–
2	1.64	1.16	0.89	0.69	0.55	0.45
3	1.66	1.29	1.07	0.91	0.79	0.69
4	1.66	1.20	1.04	0.94	0.88	0.80
5	1.63	1.39	1.29	1.24	1.18	1.15
6	1.57	1.43	1.38	1.36	1.32	1.28
7	1.57	1.46	1.41	1.39	1.35	1.30
8	1.60	1.45	1.36	1.30	1.24	1.18
9	1.57	1.41	1.32	1.26	1.17	1.10
10	1.48	1.36	1.25	1.17	1.05	0.95
11	1.57	1.45	1.34	1.24	1.11	0.99
12	1.59	1.50	1.45	1.40	1.31	1.21

TABLE 7

Manometer Readings (psi) at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section F-1, Cycle 1

Air Chamber Number	Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0
1	1.64	1.08	0.83	0.38	—	—	—	--	--
2	1.66	1.63	1.89	1.94	1.55	1.23	0.87	0.93	0.28
3	1.67	1.72	2.01	1.97	1.74	1.53	1.24	1.42	0.54
4	1.68	1.39	1.35	1.08	0.85	0.73	0.60	0.72	0.31
5	1.65	1.78	1.97	2.15	2.02	1.92	1.69	1.94	1.06
6	1.61	1.82	1.83	1.67	1.56	1.48	1.31	1.54	0.83
7	1.61	1.86	1.95	1.77	1.61	1.51	1.32	1.57	0.80
8	1.65	1.74	1.77	1.57	1.32	1.16	0.98	1.17	0.53
9	1.58	1.70	1.75	1.50	1.24	1.09	0.89	1.05	0.42
10	1.49	1.72	1.79	1.47	1.27	1.11	0.89	1.04	0.39
11	1.59	1.82	1.96	1.86	1.60	1.40	1.12	1.30	0.49
12	1.63	1.71	1.71	1.54	1.39	1.26	1.04	1.24	0.49

TABLE 8

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section F-1, Cycle 2*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.39	0.81	0.55	–	1.23	0.96	1.10	1.21	1.11	1.18
2	1.54	1.43	1.44	1.75	1.58	1.41	1.32	1.39	1.21	1.31
3	1.59	1.65	1.76	2.08	1.59	1.59	1.39	1.43	1.22	1.34
4	1.57	1.35	1.30	1.23	1.18	1.11	1.14	1.24	1.15	1.30
5	1.45	1.58	1.68	2.04	1.84	2.04	1.81	1.83	1.30	1.31
6	1.53	1.75	1.78	1.75	1.41	1.59	1.39	1.53	1.20	1.36
7	1.56	1.81	1.86	1.87	1.50	1.71	1.46	1.55	1.23	1.38
8	1.56	1.63	1.60	1.58	1.29	1.48	1.36	1.50	1.24	1.38
9	1.51	1.59	1.60	1.66	1.23	1.45	1.31	1.46	1.19	1.33
10	1.43	1.46	1.43	1.48	1.14	1.46	1.30	1.41	1.12	1.25
11	1.55	1.78	1.89	2.09	1.47	1.77	1.36	1.50	1.19	1.34
12	1.55	1.65	1.67	1.61	1.20	1.49	1.37	1.47	1.21	1.36

PRESSURE RELIEF VALVE OBSERVATIONS

1	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None
3										
4	Heavy	Heavy	Heavy	Heavy	Med.	Med.	Med.	Heavy	Med.	Med.
5										
6										
7										
8										
9										
10										
11										
12										

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi.
Multiple lines indicated repeated inflation.

Table 9. Summary of Observations Relating to Debonding of the Strapping Following the First Solar Heat Load Cycle of Shelter Section F-1

Seam Number	Observations
1	Two 1" edge lifts about 9' above air inlet valve
2	Three edge lifts 3"-4" in length on side opposite valves
3	Slight debonding at diagonal cut end of strapping
4	One 6" edge lift, one 6" point lift at diagonal cut end
5	Four small edge lifts (less than 1/2" length) in a rippled area rear valve
7	Three edge lifts less than 1" in length (about 1/4" deep)
9	Slight debonding at diagonal cut end of strapping
11	Two longitudinal tunnels, each about 3" long and 5/8" wide and present at the start of the test, elongated and merged to form a tunnel about 2 ft in length and 3/4" in width.

TABLE 10

Results of Leak Test on Shelter Section F-2

Air Chamber Number	Air Pressure (psi at Specified Time in Hours From Start of Leak Test)						
	0	0.5	1.0	1.5	2.0	14.0	15.5
1	1.95	1.77	1.69	1.63	1.56	0.78	0.72
2	1.94	1.80	1.72	1.64	1.54	0.52	0.46
3	1.99	1.89	1.83	1.77	1.70	0.85	0.79
4	1.99	1.90	1.84	1.80	1.75	1.18	1.14
5	1.97	1.75	1.64	1.55	1.47	0.82	0.78
6	2.00	1.88	1.80	1.78	1.64	0.84	0.78
7	2.03	1.88	1.77	1.68	1.58	0.66	0.61
8	1.96	1.81	1.72	1.66	1.59	1.02	0.97
9	1.79	1.39	1.21	1.11	1.04	0.59	0.56
10	1.58	0.83	0.50	0.27	<0.21	<0.21	<0.21
11	1.80	1.33	1.08	0.86	0.71	<0.21	<0.21
12	1.81	1.47	1.29	1.10	0.95	<0.21	<0.21

TABLE 11

Manometer Readings (psi) and Pressure Relief Valve Observations Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section F-2, Cycle*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.67	1.92	1.98	–	0.70	–	–	–	–	–
2	1.65	1.95	2.10	1.51	1.53	1.09	0.71	1.46	1.03	0.80
3	1.67	2.01	2.14	1.89	1.77	1.54	1.25	1.63	1.07	0.89
4	1.74	2.08	2.24	2.05	1.92	1.74	1.54	1.78	1.10	0.95
5	1.72	1.90	1.97	1.76	1.70	1.39	1.19	1.42	1.10	0.97
6	1.70	1.96	2.10	1.80	1.68	1.41	1.24	1.41	1.08	0.97
7	1.70	1.93	2.16	2.10	1.98	1.64	1.42	1.43	1.09	0.98
8	1.70	1.94	2.23	1.95	1.84	1.48	1.31	1.41	1.01	0.91
9	1.64	1.59	1.73	1.55	1.66	1.06	0.80	1.11	0.91	0.74
10	1.58	1.03	0.85	–	1.49	0.60	–	0.78	0.73	0.54
11	1.63	1.51	1.68	1.73	1.92	1.35	1.11	1.34	0.88	0.69
12	1.69	1.70	1.89	1.73	1.63	1.24	1.09	1.39	1.11	0.70
	PRESSURE RELIEF VALVE OBSERVATIONS									
1	None	Light	Heavy	None	None	None	None	None	None	None
2	None	None	Med.	None	None	None	None	None	None	None
3	None	None	Sli.	None	None	None	None	None	None	None
4	None	None	None	Med.	None	None	None	None	None	None
5	Light	Light	Med.	Heavy	Heavy	None	None	Sli.	None	None
6	None	None	Med.	None	None	None	None	None	None	None
7	None	None	None	None	None	None	None	None	None	None
8	None	None	Med.	None	None	None	None	None	None	None
9	None	None	None	None	None	None	None	None	None	None
10	None	None	None	None	None	None	None	None	None	None
11	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi
Multiple lines indicate repeated inflation

TABLE 12

Monometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section F-2, Cycle 2*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.84	1.86	1.89	1.66	1.31	1.14	1.38	1.58	1.48	1.38
2	1.78	2.03	2.18	1.89	1.46	1.21	1.31	1.46	1.41	1.33
3	1.88	2.09	2.14	1.93	1.57	1.37	1.43	1.49	1.47	1.38
4	1.84	2.12	2.20	2.04	1.70	1.53	1.63	1.73	1.45	1.40
5	1.83	2.01	1.98	1.74	1.34	1.12	1.33	1.56	1.48	1.40
6	1.83	1.96	1.93	1.74	1.37	1.17	1.36	1.53	1.49	1.39
7	1.89	2.18	2.26	2.25	1.84	1.53	1.51	1.58	1.50	1.44
8	1.88	2.15	2.19	1.99	1.56	1.34	1.40	1.54	1.47	1.40
9	1.89	1.90	1.86	1.62	1.23	1.01	1.28	1.54	1.45	1.36
10	1.90	2.14	2.28	2.39	2.05	1.83	1.94	2.07	1.60	1.35
11	1.88	2.05	2.14	1.94	1.50	1.25	1.31	1.43	1.44	1.33
12	1.88	1.84	1.85	1.60	1.20	1.01	1.27	1.52	1.45	1.35

PRESSURE RELIEF VALVE OBSERVATIONS

1	Heavy	Med.	Heavy	Light	None	None	None	None	None	
2	None	Heavy	Heavy	Med.	None	None	None	None	None	
3	None	Heavy	Heavy	Med.	None	None	None	None	None	
4	Light	Heavy	Heavy	Heavy	None	None	None	None	None	
5	Med.	Heavy	Med.	Med.	Light	None	Light	Med.	Light	
6	Med.	Heavy	Heavy	None	None	None	None	None	None	
7	None	None	None	None	None	None	None	None	None	
8	Light	Med.	Med.	Med.	None	None	None	None	None	
9	Med.	Heavy	Med.	None	None	None	None	None	None	
10	None	None	None	None	None	None	None	None	None	
11	None	None	Light	None	None	None	None	None	None	
12	Med.	Heavy	Heavy	Light	None	None	None	Light	None	

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi.
Multiple lines indicate repeated inflation.

TABLE 13

Results of Leak Test on Shelter Section IP-1

Air Chamber Number	Air Pressure (psi) at Specified Time in Hours from Start of Leak Test					
	0	0.5	1.0	1.5	2.0	15.0
1	1.73	1.59	1.49	1.38	1.29	0.66
2	1.70	1.43	1.24	1.08	0.95	<0.21
3	1.72	1.42	1.23	1.05	0.92	<0.21
4	1.64	1.39	1.26	1.14	1.04	0.25
5	1.69	1.46	1.31	1.16	1.04	<0.21
6	1.70	1.41	1.21	1.02	0.88	<0.21
7	1.73	1.54	1.40	1.23	1.10	<0.21
8	1.72	1.54	1.38	1.22	1.09	<0.21
9	1.72	1.54	1.41	1.25	1.14	<0.21
10	1.74	1.65	1.60	1.53	1.48	0.92
11	1.75	1.68	1.63	1.56	1.51	0.86
12	1.73	1.64	1.48	1.50	1.44	0.59
13	1.74	1.66	1.59	1.51	1.45	1.58

TABLE 14

Manometer Readings (psi) and Pressure Relief Valve Observations Specified Time (hrs) from Start of Solar Heat Load Test For Shelter Section IP-1, Cycle 1*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.55	1.70	1.75	1.66	1.65	1.62	1.51	1.41	1.19	1.18
2	1.52	1.62	1.76	1.64	1.53	1.56	1.35	1.31	1.18	1.11
3	1.54	1.61	1.64	1.57	1.40	1.54	1.26	1.24	1.11	1.10
4	1.48	1.53	1.57	1.55	1.43	1.49	1.26	1.25	1.10	1.10
5	1.52	1.63	1.70	1.53	1.42	1.51	1.24	1.23	1.06	1.93
6	1.51	1.61	1.44	1.64	1.46	1.53	1.19	1.22	1.13	0.93
7	1.53	1.71	1.79	1.65	1.50	1.56	1.35	1.33	1.21	1.00
8	1.52	1.70	1.83	1.75	1.69	1.69	1.50	1.43	1.23	1.07
9	1.52	1.69	1.80	1.64	1.52	1.58	1.35	1.35	1.21	1.07
10	1.54	1.73	1.80	1.77	1.69	1.65	1.54	1.50	1.32	1.31
11	1.54	1.75	1.80	1.76	1.68	1.64	1.54	1.49	1.32	1.29
12	1.55	1.74	1.80	1.78	1.68	1.62	1.48	1.43	1.30	1.28
13	1.54	1.74	1.72	1.62	1.54	1.51	1.34	1.31	1.17	1.14

PRESSURE RELIEF VALVE OBSERVATIONS

1										
2										
3	Sli.	Sli.	Sli.	None	None	None	None	None	None	None
4	Med.	Med.	Med.	Heavy	Light	Med.	None	Light	None	None
5										
6										
7										
8										
9										
10	None	Med.	Heavy	Heavy	Med.	Med.	Light	Sli.	None	None
11	None	Med.	Heavy	Heavy	Med.	Light	None	None	None	None
12	None	None	Light	None	None	None	None	None	None	None
13	None	None	Med.	None	None	None	None	None	None	None

*Dashed vertical lines indicate air chambers reinflated ~ 1.5 psi
Multiple lines indicate repeated inflation

TABLE 15

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section IP-1, Cycle 2*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.78	1.66	1.74	1.63	1.45	1.39	1.37	1.49	1.39	0.82
2	1.76	1.60	1.64	1.54	1.26	1.24	1.23	1.43	1.35	0.73
3	1.78	1.61	1.68	1.57	1.25	1.23	1.21	1.42	1.36	0.73
4	1.68	1.50	1.57	1.46	1.18	1.17	1.16	1.38	1.36	0.75
5	1.70	1.53	1.60	1.48	1.20	1.15	1.12	1.31	1.32	0.66
6	1.79	1.61	1.66	1.63	1.27	1.19	1.17	1.39	1.33	0.64
7	1.80	1.68	1.70	1.58	1.28	1.25	1.23	1.41	1.35	0.68
8	1.83	1.87	1.87	1.76	1.51	1.43	1.36	1.49	1.39	0.70
9	1.82	1.81	1.83	1.61	1.32	1.30	1.27	1.45	1.38	0.74
10	1.81	1.78	1.84	1.75	1.53	1.48	1.46	1.57	1.48	0.84
11	1.82	1.80	1.87	1.76	1.55	1.50	1.49	1.59	1.50	0.85
12	1.79	1.76	1.84	1.75	1.58	1.55	1.56	1.61	1.51	0.85
13	1.48	1.78	1.91	1.81	1.67	1.62	1.61	1.60	1.47	0.86

PRESSURE RELIEF VALVE OBSERVATIONS

1										
2										
3	Heavy	Med.	Heavy	Med.	None	None	Light	Heavy	Light	None
4	Heavy	Med.	Heavy	Med.	None	None	None	Heavy	Med.	None
5										
6										
7										
8										
9										
10	Heavy	Heavy	Heavy	Heavy	Med.	Light	Med.	Heavy	Light	None
11	Heavy	Heavy	Heavy	Heavy	Med.	None	None	Heavy	None	None
12	None	None	None	None	None	None	None	None	None	None
13	None	None	None	None	None	None	None	None	None	None

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi
Multiple lines indicate repeated inflation

TABLE 16

Results of Leak Test on Shelter Section IP-2

Air Chamber Number	Air Pressure (psi) at Specified Time in Hours from Start of Leak Test					
	0	0.5	1.0	1.5	2.0	22.0
1	1.77	1.65	1.57	1.50	1.44	<0.21
2	1.77	1.61	1.53	1.47	1.43	0.29
3	1.77	1.67	1.61	1.56	1.52	0.40
4	1.79	1.71	1.66	1.63	1.59	0.54
5	1.77	1.63	1.53	1.44	1.37	<0.21
6	1.73	1.54	1.44	1.36	1.29	<0.21
7	1.74	1.59	1.48	1.39	1.31	<0.21
8	1.73	1.58	1.47	1.38	1.30	<0.21
9	1.71	1.56	1.45	1.35	1.27	<0.21
10	1.74	1.64	1.57	1.51	1.46	0.30
11	1.79	1.69	1.60	1.53	1.47	0.23
12	1.78	1.68	1.59	1.51	1.45	<0.21
13	1.77	1.67	1.59	1.52	1.46	<0.21

TABLE 17

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section IP-2, Cycle 1*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.71	1.79	1.93	1.77	1.59	1.48	1.48	1.37	1.58	0.87
2	1.75	1.75	1.77	1.64	1.47	1.38	1.41	1.33	1.56	0.86
3	1.75	1.93	1.88	1.78	1.61	1.52	1.53	1.45	1.60	0.84
4	1.76	1.96	2.00	1.85	1.66	1.58	1.58	1.51	1.63	0.86
5	1.74	1.90	1.81	1.66	1.45	1.35	1.35	1.25	1.39	0.72
6	1.71	1.70	1.65	1.45	1.28	1.13	1.05	0.93	1.17	0.64
7	1.73	1.80	1.96	1.81	1.61	1.50	1.40	1.28	1.31	0.68
8	1.73	1.71	1.68	1.55	1.36	1.26	1.28	1.19	1.33	0.69
9	1.70	1.68	1.68	1.61	1.45	1.34	1.35	1.25	1.39	0.73
10	1.70	1.81	1.75	1.66	1.49	1.40	1.43	1.35	1.53	0.82
11	1.75	1.86	2.12	1.62	1.43	1.32	1.41	1.31	1.54	0.84
12	1.73	1.88	1.89	1.74	1.56	1.44	1.47	1.37	1.59	0.86
13	1.73	1.79	1.78	1.65	1.50	1.41	1.47	1.38	1.63	0.93

PRESSURE RELIEF VALVE OBSERVATIONS

1	Heavy	Light	None	None	None	None	None	None	
2	Heavy	Heavy	Light	None	Light	None	Med.	None	
3	Heavy	Heavy	None	None	None	None	None	None	
4	Heavy	Heavy	Light	None	None	None	None	None	
5	None	None	None	None	None	None	None	None	
6									
7	Med.	Med.	None	None	None	None	None	None	
8	Med.	Med.	None	None	None	None	None	None	
9									
10									
11									
12	Heavy	Heavy	Light	None	Sli.	None	None	None	
13									

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi
Multiple lines indicate repeated inflation

TABLE 18

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section IP-2, Cycle 2*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.68	1.86	1.78	1.75	1.33	1.56	1.42	1.30	1.48	1.37
2	1.71	1.73	1.63	1.57	1.19	1.57	1.36	1.28	1.51	1.42
3	1.72	1.86	1.78	1.76	1.35	1.59	1.48	1.36	1.53	1.41
4	1.74	2.00	1.88	1.82	1.39	1.61	1.53	1.40	1.53	1.42
5	1.70	1.83	1.74	1.62	1.16	1.50	1.26	1.21	1.36	1.31
6	1.62	1.49	1.37	1.23	0.82	1.36	0.94	0.89	1.19	1.20
7	1.68	1.80	1.83	1.78	1.28	1.61	1.34	1.21	1.29	1.31
8	1.70	1.78	1.64	1.52	1.07	1 45	1.20	1.12	1.31	1.30
9	1.65	1.65	1.58	1.58	1.16	1.51	1.30	1.24	1.37	1.30
10	1.68	1.75	1.66	1.66	1.25	1.54	1.39	1.29	1.46	1.36
11	1.70	1.75	1.65	1.60	1.18	1.56	1.34	1.26	1.53	1.39
12	1.71	1.85	1.78	1.73	1.29	1.58	1.41	1.31	1.52	1.41
13	1.71	1.80	1.66	1.67	1.28	1.59	1.44	1.34	1.55	1.44

PRESSURE RELIEF VALVE OBSERVATION

1	Med.	Light	None	None	None	None	None	None
2	Med.	Med.	None	Heavy	Light	Sli.	Light	Light
3	Med.	Med.	None	None	None	None	None	None
4	Med.	Med.	None	Light	Light	None	None	None
5	None	None	None	None	None	None	None	None
6								
7	None	Sli.	None	Light	None	None	None	None
8	Light	Sli.	None	Light	None	None	None	None
9								
10								
11								
12	Med.	Med.	None	Light	Light	None	None	None
13								

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi.
Multiple lines indicate repeated inflation.

TABLE 19

Results of Leak Test on Shelter Section IP-3

Air Chamber Number	Air Pressure (psi) at Specified Time in Hours from Start of Leak Test				
	0	0.5	1.0	1.5	15.5
1	1.71	1.69	1.66	1.59	0.99
2	1.75	1.66	1.60	1.52	0.81
3	1.76	1.73	1.68	1.60	0.75
4	1.74	1.70	1.66	1.58	0.66
5	1.67	1.56	1.52	1.44	0.61
6	1.63	1.50	1.61	1.35	0.45
7	1.71	1.66	1.62	1.53	0.58
8	1.74	1.70	1.65	1.55	0.52
9	1.71	1.70	1.65	1.55	0.56
10	1.71	1.71	1.69	1.61	0.83
11	1.71	1.68	1.66	1.58	0.81
12	1.69	1.62	1.58	1.49	0.75
13	1.68	1.59	1.53	1.43	0.54

TABLE 20

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section IP-3, Cycle 1*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.68	1.83	1.74	1.63	1.49	1.46	1.36	1.34	1.56	1.18
2	1.68	1.75	1.67	1.51	1.34	1.30	1.23	1.18	1.53	1.14
3	1.71	1.91	1.89	1.75	1.61	1.56	1.48	1.42	1.61	1.16
4	1.68	1.79	1.74	1.65	1.52	1.48	1.40	1.33	1.57	1.14
5	1.59	1.64	1.59	1.46	1.35	1.30	1.23	1.17	1.39	1.00
6	1.54	1.58	1.50	1.36	1.24	1.19	1.12	1.05	1.34	0.96
7	1.65	1.89	1.85	1.65	1.56	1.50	1.41	1.33	1.46	1.02
8	1.69	1.79	1.74	1.67	1.56	1.49	1.38	1.28	1.52	1.04
9	1.68	1.79	1.70	1.56	1.38	1.30	1.19	1.11	1.52	1.05
10	1.66	1.75	1.67	1.59	1.47	1.43	1.36	1.30	1.55	1.11
11	1.66	1.79	1.71	1.59	1.47	1.43	1.37	1.32	1.60	1.11
12	1.64	1.70	1.64	1.58	1.50	1.48	1.43	1.38	1.60	1.14
13	1.62	1.69	1.60	1.55	1.46	1.43	1.36	1.29	1.54	1.13

PRESSURE RELIEF VALVE OBSERVATIONS

1	Sli.	Heavy	Heavy	Med.	Light	Light	None	None	Light	None
2	Med.	Heavy	Heavy	Med.	None	None	None	None	Med.	None
3	Heavy	Med.	Med.	Med.	None	None	None	None	None	None
4	None	Heavy	Med.	Med.	None	None	None	None	Light	None
5										
6										
7	None	None	Light	**						
8										
9										
10	None	Heavy	Med.	Med.	None	None	None	None	Light	None
11										
12	Med.	Heavy	Med.	Light	None	None	None	None	None	None
13										

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi.
Multiple lines indicate repeated inflation.
**Connector gasket broke.

TABLE 21

Manometer Readings (psi) and Pressure Relief Valve Observations at Specified Time (hrs) from Start of Solar Heat Load Test for Shelter Section IP-3, Cycle 2*

Air Chamber Number	Manometer Readings Time (hrs) 0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1	1.68	1.79		1.62	1.44	1.34	1.29	1.24	1.15	1.40
2	1.70	1.68		1.45	1.25	1.15	1.10	1.05	1.07	1.39
3	1.71	1.86		1.76	1.56	1.45	1.39	1.33	1.14	1.42
4	1.69	1.74		1.63	1.47	1.36	1.29	1.23	1.13	1.42
5	1.63	1.54		1.40	1.23	1.14	1.08	1.02	0.91	1.32
6	1.62	1.53		1.35	1.16	1.06	1.03	0.92	0.84	1.30
7	1.67	1.81		1.66	1.51	1.39	1.29	1.19	0.93	1.35
8	1.70	1.76		1.68	1.50	1.36	1.25	1.14	0.99	1.38
9	1.69	1.74		1.55	1.30	1.16	1.07	0.98	0.99	1.38
10	1.66	1.71		1.59	1.42	1.33	1.26	1.21	1.10	1.40
11	1.66	1.71		1.58	1.41	1.32	1.27	1.21	1.11	1.41
12	1.66	1.66		1.57	1.45	1.38	1.33	1.28	1.15	1.43
13	1.64	1.62		1.50	1.38	1.30	1.23	1.16	1.15	1.47
PRESSURE RELIEF VALVE OBSERVATIONS										
1	Med.	Heavy		Heavy	Light	Light	None	None	None	None
2	Heavy	Heavy		Heavy	None	None	None	None	None	None
3	None	Heavy		Heavy	None	None	None	None	None	None
4	Med.	Heavy		Heavy	None	None	None	None	None	None
5										
6										
7										
8										
9										
10	Med.	Heavy		Heavy	None	None	None	None	None	None
11										
12	Med.	Heavy		Heavy	None	None	None	None	None	None
13										

*Dashed vertical lines indicate air chambers reinflated to ~ 1.5 psi.

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